

STIMULUS CONTROL OF PAVLOVIAN FACILITATION

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Two experiments were conducted using an autoshaping procedure with pigeons to examine whether dimensional stimulus control by a Pavlovian facilitator parallels the control established following operant discrimination training. Facilitation training consisted of the presentation of a black vertical line on a white background as the B stimulus in a feature-positive discrimination in which the A stimulus (white keylight) was followed by grain presentation only if preceded by B. In this way, B facilitates or sets the occasion for pecking at A. Subsequent testing for generalization along the line-orientation dimension produced decremental gradients when the facilitation paradigm incorporated an explicit feature-negative stimulus (B-). These results parallel the decremental control obtained following operant discrimination training and suggest that Pavlovian facilitators and instrumental discriminative stimuli are functionally equivalent.

Key words: Pavlovian feature-positive discrimination, facilitation, discriminative stimulus, generalization, line tilt, key peck, pigeon

Recently there has been considerable interest in Pavlovian feature-positive discriminations in which reinforcement occurs in the presence of one stimulus (A) when presented in combination with another stimulus (B), but not when it is presented alone (e.g., Holland, 1989a; Rescorla, 1988). A number of recent studies have provided evidence suggesting that under some circumstances, B plays a modulatory rather than an elicitive role in such BA+, A- discrimination procedures. That is, under some conditions, B fails to elicit a conditioned response (CR) but comes to function as a conditional cue to set the occasion (Holland, 1983, 1985; Ross & LoLordo, 1986, 1987) or facilitate (Rescorla, 1985; Rescorla, Durlach, & Grau, 1985) elicitation of the CR by A.

Holland and his associates (Holland, 1983, 1986; Ross & Holland, 1981) have used a feature-positive discrimination procedure with rats in which visual (B) and auditory (A) stimuli elicit topographically different CRs when separately paired with food. Light-food pairings elicit rearing (standing with both front

feet off the floor) and sitting with head in the food magazine, whereas tone-food pairings result in head jerking. Evidence that B acquires an occasion-setting function, in which it modulates the relationship between A and the unconditioned stimulus (US), was obtained when the rats acquired headjerk behavior to the A (tone) cue of serial compounds (B → A+, A-; i.e., B followed by A is a positive trial and A alone is negative) were used in training. In contrast, if simultaneous compounds (BA+, A-) were used, the rats displayed rearing and magazine behaviors. Subsequent research using this paradigm (Holland, 1989b) has shown that B can function as a conditional or occasion-setting cue in a simultaneous compound if the A stimulus is particularly loud (salient), suggesting that the B stimulus acquires a modulatory function whenever the situation is arranged such that A, rather than B, evokes the CR (Rescorla, 1986).

Rescorla and his associates (Rescorla, 1985, 1986, 1988; Rescorla et al., 1985) have used two slightly different autoshaping procedures to investigate potential modulatory functions in Pavlovian feature-positive discriminations with pigeons. In these facilitation preparations, as in Holland's occasion-setting procedure with rats, the form of the CR depends upon the conditioned stimulus (CS). Both procedures use a discrete keylight as the common element or A stimulus but differ in terms of the event

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employed as the feature or B event. One procedure uses diffuse auditory and/or visual events as B, whereas the second procedure uses a discrete keylight as the B stimulus but separates A and B in time. Directed pecking as a CR develops to the keylight stimulus when it is paired with food, but diffuse CSs and keylight CSs separated in time from the US do not evoke substantial rates of pecking. Because of these topographical differences in response form one can determine the potential function of B by examining the response form to the BA compound. Rescorla's (1985) findings with both the diffuse feature stimulus procedure and the sequential procedure, in which feature and common element were temporally separated keylights, were in agreement with those of Holland (1983) in showing that one stimulus can acquire the power to facilitate the response to another stimulus.

Regardless of whether the term *facilitator* or *occasion setter* is used, it is clear that both rats and pigeons learn a three-term hierarchical relation in which the B stimulus in BA+, A- Pavlovian discriminations controls responses to another stimulus. A number of investigators (Davidson, Aparicio, & Rescorla, 1988; Holland, 1983; Rescorla, 1985; Ross & LoLordo, 1987) have noted the operational similarity of the B stimulus in Pavlovian paradigms and the discriminative stimulus (S^D) in instrumental conditioning paradigms. In operant discriminations an S^D is defined procedurally as a stimulus in the presence of which a certain class of responses will be reinforced. Hence, the S^D signals a response-reinforcer relation, whereas the B stimulus of a Pavlovian feature-positive discrimination (henceforth termed a facilitator) signals a CS-US relation. Recent research also suggests that S^D s and facilitators share certain functional properties. Davidson *et al.* (1988) assessed the degree to which facilitator and S^D s were interchangeable in a transfer design. The results showed that (a) a facilitator augmented instrumental responding, both when presented alone and when presented in a compound with the S^D , and (b) an S^D augmented responding to a Pavlovian CS trained as a target in a facilitation paradigm.

The purpose of the present experiments was to provide some additional empirical evidence with regard to the question of the functional equivalence of S^D s and facilitators. As Thomas (1985) has recently noted one can distinguish

between a procedural definition of an S^D and a functional one. Procedurally, an S^D "sets the occasion" (Skinner, 1938) or signals the availability of reinforcement for a given response class. Functionally, an S^D is a stimulus that demonstrably controls some response characteristics such as rate of responding. Demonstrations of control require differential responding as a function of systematic changes in a specified dimension of the stimulus (Hearst, Besley, & Farthing, 1970). The present experiments explored the functional role of facilitators and S^D s. Specifically, the experiments examined whether dimensional control by a Pavlovian facilitator was analogous to the control established following operant discrimination training.

EXPERIMENT 1

One objective of Experiment 1 was to assess dimensional control by a Pavlovian facilitator. Dimensional control was assessed by testing for generalization along a line orientation dimension following Pavlovian feature-positive training using Rescorla's (1985) sequential (serial) autoshaping paradigm. Specifically, a black vertical line on a white background served as the B stimulus in a B → A+, A- discrimination in which the A stimulus (white keylight) was separated from B by the intervention of a 5-s blank key. Typically, if the presence of a line is associated with a response-reinforcer relation, a posttraining generalization test produces a decremental (excitatory) gradient (see, e.g., Honig, Boneau, Burstein, & Pennypacker, 1963) depending upon the particular discrimination procedures in effect (see Honig & Urcuioli, 1981; Mackintosh, 1977, for reviews). Dimensional control by a facilitator has not been previously explored, and these generalization tests permitted us to determine whether the gradients obtained were similar to operant control gradients. A second objective was to compare the dimensional control developed by a facilitator with that of a CS+ in a simultaneous interdimensional discrimination (see, e.g., Tomie, Davitt, & Engberg, 1976) both when the CS was signaled and not signaled by a facilitator. To this end (a) a second group of pigeons was trained in a simultaneous autoshaping procedure with reinforcement following presentation of a black vertical line on a white background but not

following presentation of a blank white key (BA+, A-) and (b) a third group received training with a blank white key as the facilitator or B stimulus and a black vertical line as the common element or A stimulus in a sequential arrangement (B → A+, A-).

METHOD

Subjects

Twelve experimentally naive White King pigeons, maintained at approximately 80% of their free-feeding weights, served as subjects. They were housed in individual cages with water and grit available.

Apparatus

The experimental chamber was a standard two-key unit with interior dimensions of 28 cm by 28 cm by 34 cm. The response keys (2.5 cm diameter) were located 22 cm from the floor and 12.75 cm apart. The right key, which was not used during the experiment, was covered with gray tape. Centered beneath the keys, 8 cm from the floor, was an opening (5 cm by 5 cm) allowing access to a hopper filled with mixed grain. Located behind the left key was an IEE® inline projector that permitted transillumination of the key with a blank white stimulus (W) and black line (0.30 cm wide by 2.5 cm high) on a white background with orientations of -90°, -67.5°, -45°, -22.5°, 0° (vertical), +22.5°, +45°, +67.5°, and +90°. The chamber was diffusely lighted from above by a 15-W bulb. Masking noise was provided by a ventilation fan and a white noise generator. Standard electromechanical control and recording equipment was located in an adjacent room.

Procedure

Magazine training was the same for all subjects. On Day 1 each bird was placed in the chamber with the food hopper raised permitting access to the grain. After the bird had eaten for approximately 20 s the hopper was lowered. Thereafter, time between hopper presentations was gradually lengthened from an average of 15 s to approximately 60 s and the time of grain availability during each presentation was systematically shortened from 15 s to 5 s. On Days 2 and 3 the birds received 44 5-s grain presentations spaced about 1 min apart.

When magazine training was completed, the birds were randomly assigned to one of three training groups and received autoshaping over the next 4 days. Autoshaping to the stimulus subsequently used as the CS (see below) consisted of 60 5-s presentations of either the vertical line (Groups S and FA) or the W stimulus (Group FB). Each of the stimulus presentations terminated with 5 s of grain access, and the intertrial interval (ITI) averaged 1 min (range, 50 to 70 s).

Pavlovian feature-positive discrimination training began on Day 8. Sessions consisted of 72 trials with an ITI averaging 1 min. Birds given facilitation training with the vertical line serving as the conditional or B stimulus in a serial arrangement (Group FB) received 48 B → A+ trials and 24 A- trials. On B → A+ trials, a 5-s presentation of the 0° line on a white background was followed serially by 5 s of blank (dark) key, a 5-s W stimulus, and 5 s of grain, and then the ITI. On A- trials, the W stimulus was presented for 5 s and was followed immediately by the ITI. The birds in the simultaneous interdimensional discrimination group (Group S) received simultaneous compound training in which the 48 daily BA+ trials consisted of a 5-s presentation of the vertical line stimulus followed by 5 s of grain presentation and the ITI. The 24 daily A- trials consisted of 5-s presentations of the W stimulus followed directly by the ITI. For birds given facilitation training with W as the facilitator and the black vertical line as the A stimulus (Group FA), training was identical to Group FB except the W and vertical line stimuli were interchanged. For all subjects, discrimination training continued until they reached a criterion of 3 consecutive days in which 95% of the responses occurred on BA+ trials.

After reaching criterion, each bird was given 2 consecutive days of line-tilt generalization tests in extinction. Each test was preceded by a 12-trial (eight BA+ and four A- trials) warm-up and, for Groups FB and S, testing consisted of the presentation of four randomized blocks of nine stimuli (eight line orientations and the W stimulus). For Group FB, each block contained (a) eight stimulus presentations in which a 5-s presentation of the W stimulus (CS+) was preceded by a 5-s presentation of a different line-orientation stimulus and 5 s of a blank (dark) key and (b) one

Table 1

Sessions to criterion and mean response rates (responses per second) to A+ and B stimuli during the three sessions prior to the generalization test in Experiment 1.

Condition	Subject	Sessions to criterion	A+ rate	B+ rate
FB	1565	29	1.01	0.28
	1638	31	2.81	0.32
	1401	21	2.25	0.08
	1417	23	2.65	0.05
S	6555	6	2.04	—
	1949	5	0.70	—
	3104	4	1.46	—
	2361	5	0.88	—
FA	2229	25	0.58	0.00
	3484	15	3.82	0.02
	1441	29	3.37	0.95
	3869	21	4.31	0.31

5-s presentation of the W stimulus alone (CS-). For Group S, each block of nine stimuli included eight 5-s presentations of a different line-tilt stimulus (CS+) and one presentation of the W stimulus (CS-). For Group FA, the generalization test consisted of six randomized blocks of eight line-orientation stimuli. Within each block, (a) four of eight 5-s presentations of line-tilt stimuli were preceded by a 5-s presentation of the W (facilitator) stimulus and 5 s of a blank (dark) key, and (b) four of the eight line-tilt stimuli were not preceded by the W stimulus. This procedure allowed for the construction of two line-orientation gradients for Group FA.

RESULTS

Discrimination Training

Acquisition data for each of the three groups are presented in Table 1. These data show that subjects given facilitation training (Groups FB and FA) took three to four times as many sessions to reach the discrimination criterion as did birds given simultaneous training. Inspection of Table 1 also shows that rates of responding to the facilitator were generally low (zero or near zero for 4 of the 8 birds in Groups FA and FB) in comparison with A+ responding.

Generalization Testing

For each subject, separate generalization gradients were constructed based on the absolute number of responses to the CS over the two postdiscrimination test sessions. For Group

FB subjects, the gradients display responding to the W stimulus as a function of the line-orientation value of the preceding facilitator stimulus. For Group FA subjects, the gradients reflect responding to the line-tilt stimuli as a function of the presence or absence of the preceding W stimulus. For Group S subjects, the gradients present responding to the line-orientation stimuli alone. Because little responding occurred to facilitator stimuli (line-tilt stimuli for Group FB or the W stimulus for Group FA) during generalization testing, these data are not shown. Moreover, responses to the W stimulus alone (CS-) for Groups FB and S are not shown because none occurred. These absolute gradients are shown in Figure 1 along with mean relative group gradients for each of the groups. The mean gradients (constructed by averaging individual relative gradients) eliminate subject differences in the absolute level of responding by displaying the proportion of total responding to each line orientation.

For subjects given facilitation training with the vertical line as the facilitator (Group FB), the relative mean gradient was rather flat, indicating little or no control by the line-orientation dimension. For Pigeons 1638, 1565, and 1401, the absolute gradients are in close agreement with the mean gradient in showing no systematic variation in responding as a function of line orientation. Only Bird 1417 showed a somewhat systematic decremental gradient with most responding to the 0° line.

For subjects given simultaneous interdimensional training (Group S), the mean relative gradient was strongly decremental with a peak at 0°, indicating clear stimulus control along the dimension of line orientation. Each of the individual gradients was also decremental with peak responding at the training stimulus.

For birds given facilitation training with the blank white key as the facilitator (Group FA), gradients were obtained both when the line orientation values were preceded by the facilitator (B → vertical line) and when they were not (line only). As can be seen in Figure 1, both for the mean and for individual birds, gradients were clearly decremental when the line values were preceded by the facilitator (filled circles). However, in the absence of the facilitator, the line-orientation stimuli failed to control responding (i.e., a flat control gradient emerged; open circles).

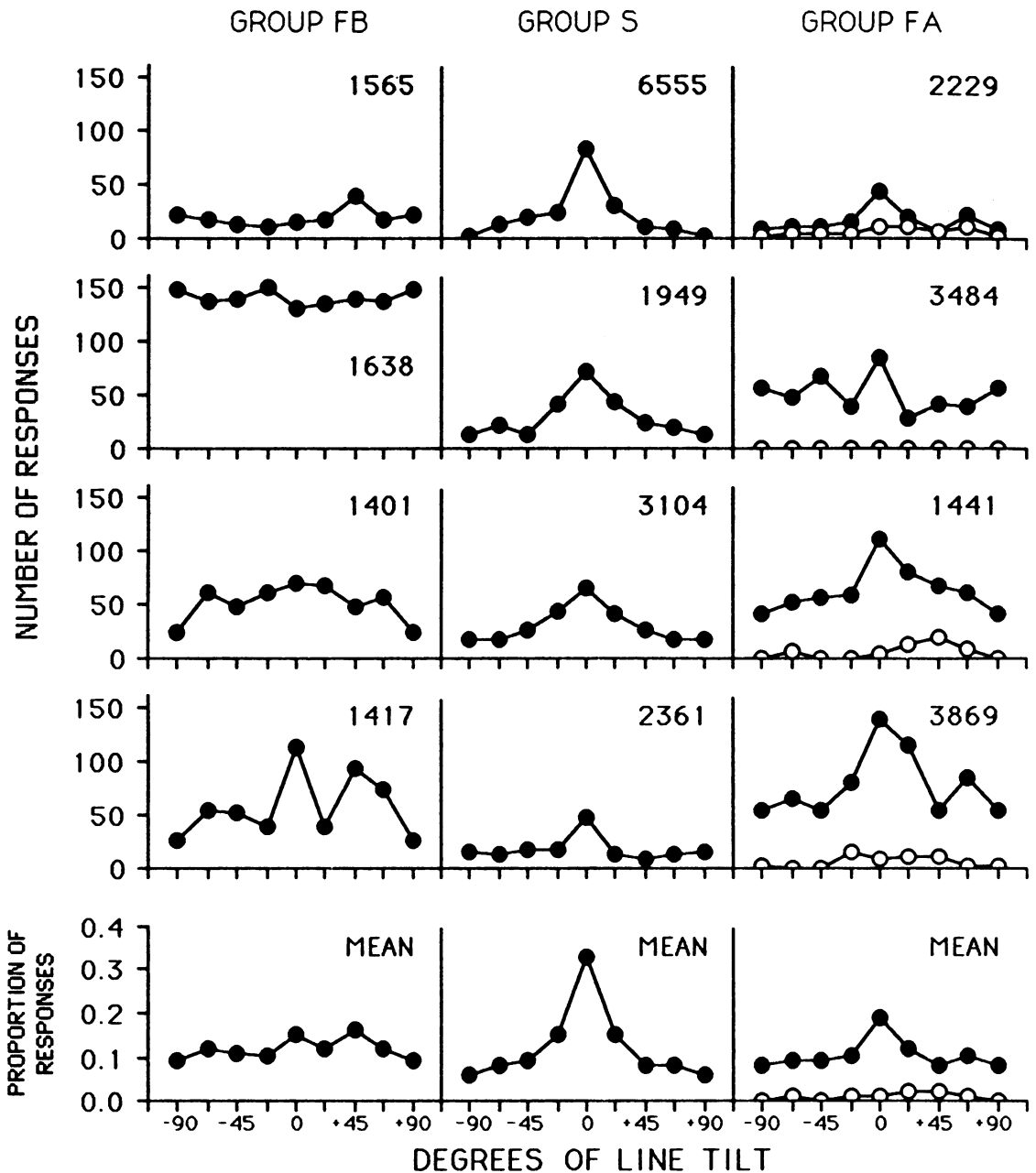


Fig. 1. Individual and group mean line-orientation generalization gradients following discrimination training in Experiment 1.

DISCUSSION

The major finding of Experiment 1 was that the line's orientation failed to control responding in a generalization test for subjects trained on a sequential feature-positive Pavlovian discrimination in which the presence of a vertical line signaled the occurrence of food with the termination of the CS and the absence of the

vertical line signaled no food following CS termination. This failure of a Pavlovian facilitator to differentially control responding to a CS conflicts with the dimensional control established in operant discriminations employing feature-positive discriminations. Both Honig et al. (1963) and Hearst (1969) obtained strongly decremental control gradients using operant procedures in which a black ver-

tical line was the distinctive feature of S+ and a blank white key was the common feature of S- (see also Farthing, 1971; Furrow & LoLordo, 1975).

The facilitator's failure to control responding also conflicts with control gradients obtained following training on operant conditional discriminations. Using procedures very similar to Pavlovian facilitation except for the presence of instrumental contingencies, Bowers and Richards (1986) obtained line-orientation gradients following successive (one key) symbolic matching-to-sample training. Specifically, one group of pigeons received food for responding to a red comparison stimulus if a previously presented stimulus (sample) had been a black vertical line on a white background (VR+) but not if the previous sample had been a white light (WR-). Conversely, responding to a blue comparison stimulus was reinforced after a white sample stimulus (WB+) but not after black vertical line (VB-). In the generalization testing phase of their experiment during which the line orientation was systematically varied, they found decremental control gradients when the comparison stimulus was the red keylight and incremental (v-shaped) gradients when the comparison stimulus was the blue light.

Thus, it would seem that a Pavlovian facilitator signals a CS-US relation just as an S^D signals a response-reinforcer relation, but unlike the S^D, the facilitator fails to enter into a controlling relation. However, before concluding that facilitators and S^Ds fail to share functional similarities, it is important to note possible alternative explanations. One interpretation is that irrelevant stimuli may have overshadowed control by the line's orientation. This view is supported by the findings of Rudolph and Van Houten (1977), who found that a tonal S^D acquired control over a pigeon's key pecking when the response key was dark but was overshadowed by the presence of a keylight. In the present experiment it seems reasonable to suggest that the line's orientation failed to acquire control because it was overshadowed by some redundant feature of the visual stimulus. That is, because a 5-s presentation of the black vertical line on a white background predicted reinforcement following CS termination and the absence of any stimulus predicted no food after the CS, the birds were not trained to discriminate solely on the

basis of the vertical line; thus, any visual feature may have acquired control. In fact, the line was also redundant with the temporal distribution of key illuminations. That is, on positive trials the CS was preceded by 5 s of dark key, whereas on negative trials the CS was initiated following approximately 60 s of blank key.

An alternative explanation that may also preserve a parallel between dimensional stimulus control by S^Ds and facilitators is that the difficulty of the discrimination precluded the acquisition of control by line orientation. A number of investigators (Boneau & Honig, 1964; Richards, 1979; Sutherland & Mackintosh, 1971) have suggested that the acquisition of control by a nonessential feature (orientation of the line was not a characteristic of the facilitator differentially correlated with reinforcement) is a function of task demands. With simple discriminations, nonessential features have a chance to control behavior, whereas more difficult discriminations, like the conditional discrimination of the present experiment, keep nonessential features from acquiring control.

The decremental gradients observed for the simultaneous group are consistent with previous investigations of stimulus control following Pavlovian interdimensional discriminations. Tomie *et al.* (1976) obtained decremental wavelength gradients following interdimensional autoshaping with pigeons, and Moore (1972) found decremental tonal frequency gradients after interdimensional eyelid conditioning with rabbits.

Particularly noteworthy is the finding that both the Pavlovian facilitator and the orientation of the line controlled responding in Group FA during the generalization test. That is, generalization testing produced either decremental or flat gradients depending on the presence or absence of the facilitator. The recent findings of Bowers and Richards (1986) from a second group of birds treated similarly to Group FA (except for the instrumental contingency) are of considerable interest in relation to this result. In their successive matching-to-sample task, responding to a black vertical line on white background produced food if the previous sample was a blue light (BV+) but not if the sample had been red (RV-). Alternately, responding to a white light produced food following a red sample (RW+) but not

a blue one (BW-). In agreement with the results of the present study, they obtained decremental gradients when the line-orientation stimuli were preceded by the blue sample. However, when the line-orientation stimuli were preceded by the red keylight, incremental control gradients emerged in contrast to the flat gradients obtained in the present experiment when the line stimuli were not preceded by the W stimulus.

EXPERIMENT 2

In the foregoing discussion, it was suggested that dimensional control by the Pavlovian facilitator failed to develop because the lines' orientation was overshadowed by some feature of the visual stimulus. Overshadowing seemed likely because an explicit B- (any stimulus preceding A- in the B → A+, A- discrimination) was absent from the discrimination procedure, unlike either operant feature-positive (Hearst, 1969; Honig et al., 1963) or conditional (Bowers & Richards, 1986; Richards, 1979) discriminations in which an explicit S- was present and stimulus control was established. To test the possibility that the absence of an explicit B- was responsible for the flat control gradients of Group FB, the primary objective of Experiment 2 was to assess stimulus control following a Pavlovian feature-positive serial discrimination in which an explicit stimulus precedes A-. Specifically, on negative trials, a 5-s white keylight preceded the A stimulus (white keylight) followed by a 5-s delay signaled by a blank key. The positive trials were identical to those of Experiment 1 and consisted of the presentation of the A stimulus preceded by a black vertical line on a white background and the blank key delay. This change converts the facilitation procedure of Experiment 1 into a true interdimensional discrimination, which contrasts a black vertical line on a white background (B+ or positive facilitator) with the white background alone (B- or negative facilitator).

On the basis of operant discrimination studies with pigeons (Jenkins & Harrison, 1960; Switalski, Lyons, & Thomas, 1966), one would expect steeper line-tilt gradients for birds trained with the true interdimensional procedure than for birds trained without an explicit negative cue. Moreover, for comparison purposes a second group of pigeons was trained

with an explicit negative cue (B-) on the same dimension as the positive facilitator (B+). That is, they were given intradimensional discrimination training in which a black vertical line on a white background served as B+ and a black horizontal line on a white background served as B-. If S^Ds and facilitators share functional properties, then birds given intradimensional training should show sharper control gradients than birds trained on the interdimensional discrimination, as shown with operant discrimination studies with pigeons (e.g., Hanson, 1959; Jenkins & Harrison, 1962).

Experiment 2 also addressed the possible role of the instrumental contingency in the production of stimulus control gradients. Rachlin (1976) has argued that gradients obtained following instrumental conditioning are sharper than those obtained following comparable Pavlovian conditioning (but see White & Braunstein, 1979). Accordingly, it is possible that decremental control failed to develop in Group FB because of the absence of a response-reinforcer contingency. This notion receives indirect support from the observation that some operant generalization studies (see, e.g., Guttman & Kalish, 1956; Hanson, 1959) have obtained decremental gradients following nondifferential single-stimulus training. To assess the influence of an instrumental contingency on dimensional control, a third group of birds received training on a B → A+, A- operant discrimination.

METHOD

Subjects and Apparatus

The subjects were 12 White King pigeons maintained as in Experiment 1. Eight birds were experimentally naive, and 4 birds (1565, 1638, 1401, 1417) had served as subjects in Group FB of Experiment 1. The apparatus was the same as in Experiment 1.

Procedure

The experimentally naive subjects were magazine trained using the same procedures as in Experiment 1. Following magazine training, they were randomly assigned to one of two discrimination groups. For birds assigned to Group FB-INTER, autoshaping and Pavlovian discrimination training were identical to that of Group FB (Experiment 1) ex-

Table 2

Sessions to criterion and mean response rates (responses per second) to A+ and B stimuli during the three sessions prior to the generalization test in Experiment 2.

Condition	Subject	Sessions		
		to crite- rion	A+ rate	B+ rate
FB-INTER	7233	16	3.39	0.20
	3869	26	4.24	0.87
	6513	12	1.82	0.19
	4416	26	3.76	0.34
FB-INTRA	1565	5	0.55	0.07
	1638	14	3.37	0.32
	1401	14	1.28	0.00
	1417	7	1.33	0.00
FB-OPER	4794	14	2.81	0.24
	10718	32	2.71	0.67
	4412	14	3.31	0.03
	3210	12	3.15	1.26

cept for the presence of a 5-s white keylight (B-) preceding the A stimulus on negative trials during discrimination training. For Group FB-OPER, training was identical to that of Group FB except for the presence of an instrumental response-reinforcer contingency during both shaping and discrimination training. Instead of 4 days of autoshaping, the birds were hand shaped and were then exposed to a fixed-ratio (FR) 10 contingency for 4 days during the 60 daily presentations of the W stimulus. During discrimination training the contingency was at least one peck to the W stimulus. If subjects did not respond to the W stimulus (A+) following the black vertical line or B stimulus, the 5 s of grain access was cancelled. The birds that had served as subjects in Experiment 1 were assigned to Group FB-INTRA and were trained identically to Group FB-INTER birds, except that a 5-s presentation of a black horizontal line (B-) preceded the A stimulus on negative trials during discrimination training.

Finally, for all birds the discrimination criterion and generalization testing procedures were identical to Experiment 1. All birds received four blocks of nine stimuli (eight line-orientation stimuli and the W stimulus) with each block containing (a) eight stimulus presentations in which a 5-s presentation of the CS (W stimulus) was preceded by a different line-tilt stimulus and 5 s of blank (dark) key

and (b) one presentation of CS- (the W stimulus alone).

RESULTS

Discrimination Training

Table 2 presents the acquisition data for each of the three discrimination groups. Group FB-INTRA subjects had served in Experiment 1 and as a result reached discrimination criterion in fewer sessions than the other groups. (The mean days to criterion for Group FB-INTRA was 10 compared to 20 and 18 days for Groups FB-INTER and FB-OPER, respectively.) Of greater interest are the rates of responding to the positive facilitator (B+) and A+. As in Experiment 1, the rate of responding to B was low ($M = 0.35$ responses per second) in comparison to A+ ($M = 2.64$ responses per second).

Generalization Testing

Figure 2 shows the absolute generalization gradients for individual subjects and a mean relative group gradient for each of the discrimination groups. The gradients display responding to the CS (W stimulus) as a function of the line orientation of the preceding facilitator stimulus. As in Experiment 1, so little responding occurred to either CS- or directly to line-tilt stimuli that these responses are not displayed graphically.

For subjects given facilitation training with the black vertical line as B+ and the blank white key as B- (Group FB-INTER), the mean gradient peaked at vertical and, when the line's orientation tilted away from 0°, relative responding decreased. All of the individual gradients show variation in responding as function of line orientation. Three birds (7233, 6513, and 4416) showed a decremental pattern, with most responding to the 0° line. Subject 3869 showed a somewhat decremental pattern, but with slightly more responding to the +67.5° line than to the training stimulus.

For subjects provided intradimensional facilitation training (Group FB-INTRA) with the vertical line as B+ and the horizontal line as B-, inspection of both mean and individual gradient reveals sharp stimulus control, shown by the steeply sloped decremental patterns with most responding to the vertical orientation.

For birds given facilitation training without an explicit B- but with an instrumental con-

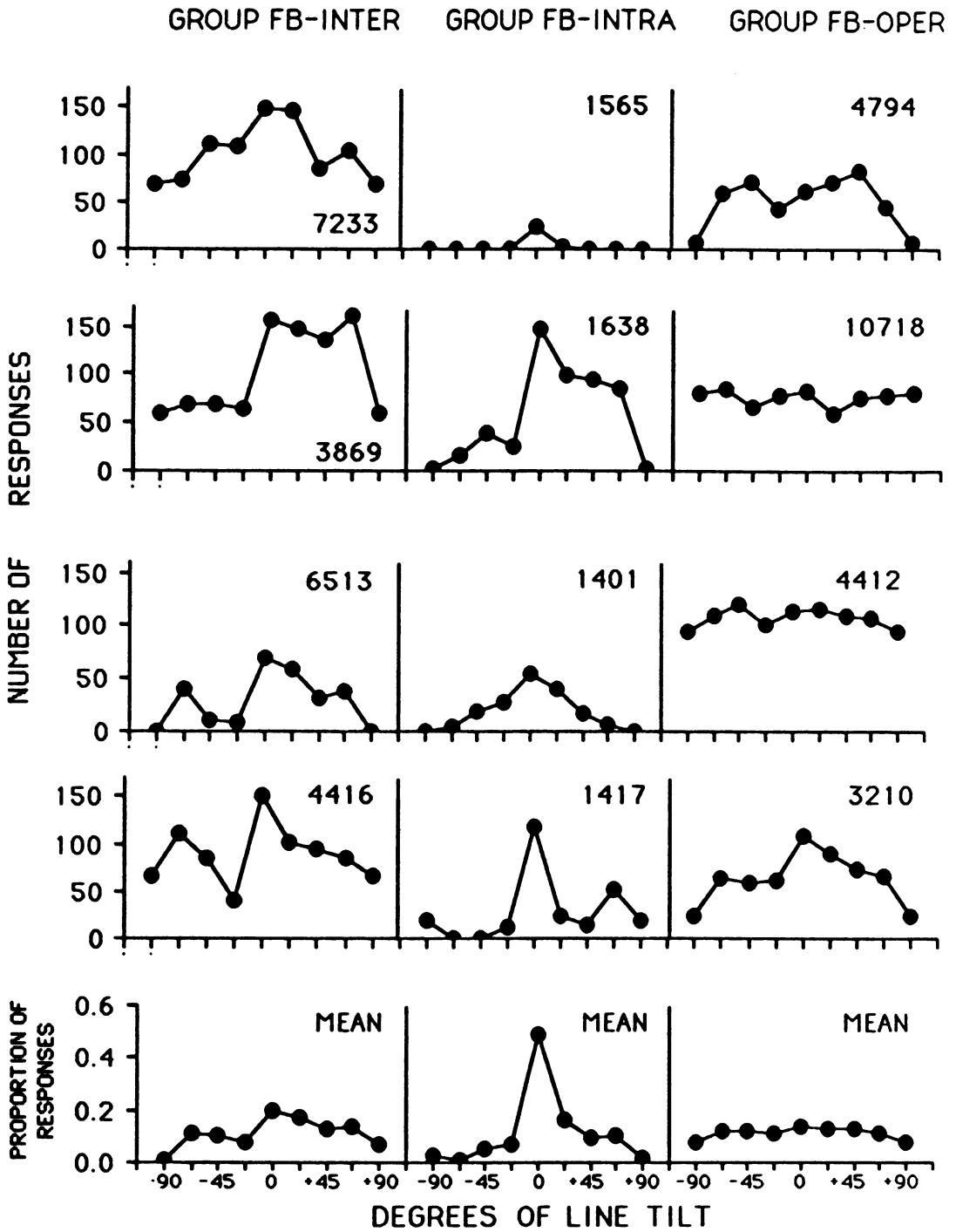


Fig. 2. Individual and group mean line-orientation generalization gradients following discrimination training in Experiment 2.

tingency (Group FB-OPER), both the mean gradient and three of the individual gradients (Birds 4794, 10718, and 4412) show flat profiles, indicating little or no control by the line's orientation. Only Bird 3210 showed a moderately decremental gradient, with most responding to the training stimulus.

DISCUSSION

The results of Experiment 2 demonstrate that dimensional control by a Pavlovian facilitator, assessed in terms of line-tilt generalization gradients, parallels that of an operant S^D following analogous inter- and intradimensional discrimination training. The addition of an explicit B- (Group FB-INTRA) to the standard facilitation paradigm (Group FB of Experiment 1) led to the establishment of decremental control. This finding is in agreement with the decremental control obtained following operant interdimensional discrimination training (Hearst, 1969; Honig *et al.*, 1963; Switalski *et al.*, 1966). Moreover, when compared with interdimensional training, the intradimensional subjects (Group FB-INTRA) produced sharper control gradients that are consistent with the findings of operant investigations of stimulus control with two stimuli that lie on the same continuum (e.g., Hanson, 1959; Hearst, 1969). Failure to obtain a peak shift, a common finding with intradimensional training, most likely resulted from the fact that the horizontal line (B-) anchored both ends of the line-tilt continuum and thus prevented displacement of the distribution's peak away from the centrally located B+.

Control by the line's orientation in Group FB-INTER also resembles the control established by the conditional cue in a matching-to-sample task. In these conditional discrimination tasks, the sample cue is considered to be the conditional cue, whereas the comparison stimuli, which are temporally closer to reinforcement, are considered to be the discrimination cues (Thomas & Schmidt, 1989). Bowers and Richards (1986) found that when a vertical line served as the sample line during a one-key symbolic matching-to-sample task, generalization testing produced decremental generalization gradients.

The finding that the line's orientation did not control responding for subjects given facilitation training without an explicit B- but with an instrumental contingency (Group FB-

OPER) does not support Rachlin's (1976) view that sharper generalization gradients will result from the imposition of an instrumental contingency. Rather, the similarity in control gradients for Group FB and Group FB-OPER suggests that the presence of an instrumental contingency does not affect the sharpness of gradients. However, it should be noted that, because the lines' orientation failed to control responding for either group of birds, a better test of Rachlin's (1976) suggestion would be a comparison of Group FB-INTRA with a comparable instrumental contingency group.

GENERAL DISCUSSION

In the experiments reported here, we evaluated whether dimensional control by a Pavlovian facilitator parallels that established following operant discrimination training. At issue was whether the procedural similarity in establishing facilitators and discriminative stimuli would lead to functional equivalence in terms of dimensional control.

In Experiment 1, serial feature-positive discrimination training failed to endow a vertical line feature stimulus with dimensional control. That is, the facilitator or B stimulus failed to control responding to the common element or A stimulus as an S^D controls responding that produces reinforcement. This absence of stimulus control by the facilitator along the dimension of line orientation was not surprising given that the B \rightarrow A+, A- discrimination lacked an explicit negative stimulus, unlike comparable operant discrimination procedures (Hearst, 1969; Honig *et al.*, 1963).

Experiment 2 confirmed that the line's orientation did control responding when an explicit negative feature was added to the facilitation procedure. The birds showed decremental generalization gradients when a blank white stimulus preceded the common element (A) on negative trials. Moreover, similar to findings with operant discriminations (Hanson, 1959; Hearst, 1969), sharper control was established in a second group of birds for which the feature-negative stimulus was on the same dimension as the feature-positive stimulus.

Taken together, the results of Experiments 1 and 2 demonstrate that S^D s and facilitators share similarities in dimensional control. That is, the value of an antecedent stimulus (facil-

itor or S^D) determines the probability of responding irrespective of training paradigm. Thus, the present results join those of others (Davidson et al., 1988) in suggesting that instrumental S^Ds and Pavlovian facilitators are functionally equivalent.

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